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Home range size of adult raccoons (*Procyon lotor*) in Germany

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The raccoon (*Procyon lotor* L.) is a Central- and North American carnivore (Kaufmann 1982) and was introduced into Europe 70 years ago (Müller-Using 1959). For the first time home range sizes of raccoons were studied outside the Americas (Hohmann 1998). The study was conducted between December 1992 and April 1996 in the southern Solling forest, a wooded variegated sandstone plateau in Lower Saxony, Germany (51° 41′ N, 9° 32′ E). The terrain is elevated between 100–350 m. The climate is oceanic with mild winters and cool summers. This area consisted of 66% mixed forests with a patchy distribution of different tree species (mainly beech *Fagus sylvatica*, oak *Quercus robur*, and *Q. petrea*, and spruce *Picea abies*). 27% of the area was designated as agricultural fields, 6% as human settlements, and 1% as watersheds (Hohmann 1998).

The forested parts af the study area were mostly fenced to prevent ungulate species (in particular red deer, *Cervus elaphus*) from damaging adjacent agricultural lands.

Between 12 and 27 traps were baited with sardines and plum jam within an area of 3,000 ha. After a baiting period of 29 to 40 days only three to five traps were set simultaneously for several consecutive days. Traps were checked every two to three hours during the night. For ease of checking and to prevent disturbance of the trap sites, radio transmitters were installed at the traps. Upon capture, raccoons were anesthetized with a mixture of ketamin hydrochloride and xylazin (20 mg : 1 mg per kg body weight). The anesthetized raccoons were weighed, sexed, aged (see Grau et al. 1970), marked with a transponder, and finally radiocollared. A collar weighed between 90 g and 155 g (which is 1.8% to 3% of a 5 kg raccoon). Each captured raccoon was released at the capture site.

Seven adult males (older than 24 months, for details see Hohmann 1998) and eight adult females (older than 12 months) were radio-tracked on average once per day and four times per night. To reduce autocorrelation of location data successive fixes were separated by a minimum of 60 min., but otherwise taken on an abitrary sampling regime (Rooney et al. 1998). In total 6378 fixes were obtained, resulting in a mean of 425 fixes per individual (SD = 284). Of those approximatly 60% were night fixes. Each data set was separated into summer and winter seasons (see Tab. 1). Home ranges were determined by using both a Convex-Polygon (MCP, Mohr 1947) and a Kernel estimator (CWK, Worton 1987).

Each seasonal data set was considered as unbiased by sample size if the size of the home range did not increase over 20 added fixes. Not all individuals were studied for an equal number of seasons. To reduce the excessive influence of those individuals studied for long periods we took the mean of the same seasonal data for these individuals (Harris et al. 1990).

The home range median of adult male home ranges over both seasons was 1236 ha (MCP) and 680 ha (CWK) respectively, the corresponding value for adult females was

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Table 1. Summer and winter home range of raccoons in the Solling, Germany, 1992–1996. Values in the row "range" refer to single seasonal home ranges. MCP: 100%-Minimum Convex Polygon-estimation; CWK: 95% Core-Weighted-Kernel-estimation, optimal smoothing factor by sixth square root of SD.

	Summer (16.4.–15.10.)				Winter (16.10–15.4)			
	Adult males		Adult females		Adult males		Adult females	
	MCP (ha)	CWK (ha)	MCP (ha)	CWK (ha)	MCP (ha)	CWK (ha)	MCP (ha)	CWK (ha)
Median	1 420	784	543	257	977	622	330	166
Mean	2 099	1 012	677	374	1 400	754	553	273
SD	1 830	719	403	356	1 047	526	547	227
Range	661–5 815	282–2 475	385–1 572	144–1 391	391–6 543	125–3 348	150–1 729	92–724
N	7	7	7	7	6	6	7	7

514 ha (MCP) and 243 ha (CWK) respectively (Tab. 1). Thus, adult males had approximately 2 to 3 times significantly larger home ranges than adult females (Mann-Whitney Rank Sum Test, summer: $p < 0.01$; winter: $p < 0.05$). Although summer home ranges of adult raccoons tended to be 23% to 50% larger than their winter home ranges this difference was not significant (Tab. 1, Mann-Whitney Rank Sum Test, $p > 0.05$).

Apart from one study in the unforested prairies of North America (Fritzell 1978) raccoon home ranges in Germany are the largest measured (Tab. 2). One reason could be that old oak stands, which provide important food sources like acorns, shelter and den sites (Kaufmann 1982; Hohmann 1998) were scattered in small patches of less than 50 ha and made up only 20% of the whole forest. Consequently, there is evidence that raccoons have to roam over larger areas to compensate for an inferior habitat.

Another reason could have been that oak forests in Germany in general are of lower diversity than in northern America (Ellenberg 1982; Sork et al. 1993). Thus, acorn masting events in Germany might be more pulsed and more coordinated than in America (Burschel and Huss 1997; Sork et al. 1993). Thus, the observed raccoons might have to cope with years in which acorns are scarce. They may again have to roam over larger areas to include enough oak forests into their home range to meet their needs.
A third effect could have forced the studied raccoon population to use larger areas: In the last decade the fenced red deer population reached high densities of more than 5 individuals per 100 ha (C. v. Prolius, pers. comm.). The red deer is a powerful browser and can reduce the available understory, and this in turn could have reduced the availability of food sources for raccoons.

It is noteworth that a rough estimation of the raccoon population density in the study area yields 2 to 4 individuals per 100 ha (Hohmann 1998). This estimate is based on a steady increasing recapture rate reaching 4 recaptures per one new capture in the last 19 months of the study. Compared with other studies providing estimates on population densities in forested areas (Endres and Smith 1993; Gehrt 1994; Kaufmann 1982; Seidensticker et al. 1988) this is a fairly low density and again indicates the apparent poor quality of the habitat in the study area.

Apart from the above-mentioned differences in the absolute quantities of the areas used by the raccoons, intrasexual differences were similar to their American counterparts (Gehrt and Fritzell 1997).

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Table 2. Comparison of home ranges sizes of adult raccoons from different study areas in North America and one study area in Germany (this study). Authors considered in this table calculated the home ranges on a monthly time base and tracked the animals over a 24-hour cycle. All authors used radiotelemetry and Minimum-Convex-Polygon estimator (MCP) or a Kernel estimator (KERNEL) for determining home range areas. List arranged according to size of home range.

				Estimator MCP		Estimator KERNEL	
Publication	Location	Habitat	Definition of given values	Home range of adult males (ha)	Home range of adult females (ha)	Home range of adult males (ha)	Home range of adult females (ha)
Fritzell (1978)	North Dacota	rural	mean	2560	806		
this study	Lower Saxony	mostly forest	mean	1776	615	893[1]	324[1]
this study	Lower Saxony	mostly forest	median	1236	514	680[1]	243[1]
Lehman (1984)	Indiana	rural	mean	486	264		
Gehrt and Fritzell (1997)	Texas	partly rural/forested	median	339	79	416[2]	90[2]
Glueck et al. (1988)	Iowa	partly rural/forested	mean	131	79		
Johnson (1970)	Alabama	mostly forest	1 individual	93			
Urban (1970)	Ohio	marshland	mean	88			
Rosatte et al. (1991)	Ontario	urban	mean	42			
Hoffmann and Gottschang (1977)	Ohio	urban	mean	16	4		

[1]: 95%-Core-Weighted-Kernel
[2]: 95%-Adaptive Kernel

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